Addressing concerns with the NSC: An analysis of first-year student performance in Mathematics and Physics

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In this article we present a statistical comparison of the mid-year Mathematics and Physics results for students in the University of Cape Town’s engineering programmes over a five year period. The particular focus is on the disaggregated group of students who wrote the 2008 NSC examinations in comparison with other groups. Concerns were raised after the 2008 NSC Mathematics results showed a marked increase in high marks resulting in more students meeting the engineering entrance requirements than in previous years. Scepticism about the NSC Mathematics results and the related increased intake of first year students has lead to speculation about the reasons for weak mid-year Mathematics I and Physics I results. This study draws its empirical data from the mid-year course results for the years 2009, 2007 and 2005. The results indicate that the South African matriculants who moved directly from school to university, show a marked decline in both Mathematics and Physics. However, the 2007 Mathematics results for the South African students indicate that this decline cannot only be attributed to the 2008 matriculation examinations. The data also suggests that increasing the university entry criteria based on NSC marks may not have a marked effect on the performance of the first year students.

Introduction

It is clear that countries with sustained economic growth are also those where education has been prioritised. Furthermore, graduates with high level skills in the Sciences and engineering are crucial for national development (see for example South African Government, 2008). Much has been said about the need for a decisive response from higher education institutions to the critical skills shortage in Science and engineering in South Africa. There can be little argument with the premise that the ‘core business’ of higher education is the production of high quality graduates (Scott, Yeld & Hendry, 2007, p. 6)

In spite of some important accomplishments in the higher education sector since the end of the apartheid, participation in higher education is still far from satisfactory: recent calculations based on the 2005 HEMIS²⁶ data indicates that the gross participation rates in higher education in South Africa are as low as 16% in the 20-24 year old age group (Scott et al, 2007). The “pool” from which suitable Science and engineering candidates are selected is even smaller: 20% of the 2008 National Senior Certificate (NSC) candidates achieved a pass that allowed them access to admission to degree studies at higher education institutions, and only 7.9% of the candidates achieved more than 60% in the 2008 NSC Mathematics examination – a requirement to enter engineering programmes (Department of Education, 2008). Small though this selection pool may be, it still represents the top students of their age cohort. Given these alarming statistics, we would argue that the view that the large majority of current Science and engineering students simply ‘do not belong’ in higher education is difficult to justify. It is in this context that the current study has been undertaken.

Engineering programmes are considered cognitively demanding and require at least two years of university Mathematics. Selection into these programmes is based on one’s marks achieved in the final

²⁶ HEMIS is the Higher Education Management and Information System
school leaving examinations. Up till now entrance criteria have been calculated according to a points system in which Mathematics, Physical Science and English (to a lesser extent) marks are weighted more heavily. Concerns were raised after the 2008 NSC Mathematics results showed a marked increase in numbers and pass rate over previous years. A panel of experts who investigated the matter found that the 2008 NSC Mathematics examination did not discriminate sufficiently between candidates, particularly at the top end of the results (Department of Education, 2009). This resulted in a disproportionate number of students achieving the highest Mathematics symbols. For universities such as UCT, using a ‘points’ system in which Mathematics points are doubled in selecting candidates into programmes like engineering, this meant that significantly more students met the minimum requirements and were accepted into Science and engineering programmes. The 2009 first-year student intake at the University of Cape Town saw an increase of 30% into the Faculty of Engineering and the Built Environment and 8% into the Science Faculty. A similar pattern unfolded at other universities in South Africa.

Since the 2009 intake is the first product of a new curriculum and teaching philosophy (Outcomes Based Education), it is not surprising that this cohort’s progress in the higher education system has been subjected to scrutiny. Scepticism about the NSC Mathematics results and the consequent large intake of first year students has lead to speculation about weak mid-year Mathematics I and Physics I results. It has been argued publically in the media (and less publically in staff rooms) that the weaknesses in the school Mathematics 2008 examination are directly responsible for the poor performance in Mathematics I and Physics I (Serrao, 2009).

The National Benchmark Tests Project (NBTP) report was released at the time of writing this article. One of the objectives of the project was to “assess the relationship between higher education entry level requirements and school-level exit outcomes” (NBT, 2009, p.1). 906 Engineering first year students and 648 Science students wrote the NBTs during orientation week at the University of Cape Town. The Mathematics NBT set out to measure how much of the new secondary school curriculum has been mastered. The report shows that only 7% of the engineering students achieved at the ‘Proficient’ level (deemed not to require additional assistance to perform at the degree level). 73% of the engineering students performed in the ‘Intermediate’ category and those at the bottom end of this category are expected to require additional support in the form of augmented programmes, extra tutorial help, etc. An alarming 20% of the engineering students were found to have only ‘Basic’ mathematical skills and would likely need to be placed in an extended programme.

The disappointing mid-year Mathematics and Physics results throughout the country; fuelled by the evidence from the NBT tests that many students from the new school system are underprepared for success in Higher Education are raising a number of questions. Just how critical is the role of the inflated/undiscriminating school Mathematics results in understanding the disappointing mid-year course results? In other words, to what extent is the “new” secondary school Mathematics the cause of the alarming June Mathematics I results? In order to address the large number of underperforming students should universities perhaps be adjusting their entry points criteria to exclude these underperforming students? On the other hand, the argument has been made in some circles that although class averages and pass rates are down; this might not impact significantly on total number of successful students. A larger intake might actually imply a larger number of students passing the courses. And overarching these details are questions of whose responsibility is a decisive response to the current situation, and what form should/could any remedial action take?

In this article we present a statistical comparison of the mid-year Mathematics and Physics results for students in the University of Cape Town’s engineering programmes over a five year period. The particular focus is on the disaggregated group of students who wrote the 2008 NSC examinations in comparison to other groups.

The Study
This study draws its empirical data from the mid-year marks for first-year Mathematics and Physics courses taken by mainstream students on the four year engineering programmes. For comparative
purposes we have drawn on three sets of data for each course; the mid-year course results for 2009, 2007 and 2005. The data are interrogated in the context of the following questions:

- Do the three sets of results reveal anything about the stability of the courses under review?
- Do the results support the anecdotal view that student success in these courses has declined markedly this year?
- How have the increased enrolments in the 2009 Physics and Mathematics courses impacted the distribution of achievement through each course?

The data consists of a combined mark for three class tests (including the June test written during the exam session) for both the Mathematics and Physics course. In the case of Mathematics, the mark is an average of all three tests. In the case of Physics, it is a weighted average with the June test contributing two thirds of the mark. The cumulative marks for 2007 and 2005 have been calculated in a similar way, although in 2005 there were only two class tests for Mathematics, which we have averaged; and in both 2007 and 2005 there were three class tests prior to the June test in Physics. To ensure consistency in the data, the third class test has been excluded from the analysis to follow. It should be noted that there are other assessments that contribute to the marks; however we have not used them for the purposes of this analysis, rather restricting our comparisons to the weighted average of three tests.

In our analysis we have grouped students in each year into the following categories (students on the extended programme were not included in the data as they participate in alternative Mathematics and Physics courses):

1. RSA matric: Students who wrote the South African matriculation examinations and then proceeded directly to the first year courses;
2. RSA matric + gap: Students who wrote the South African matriculation examinations and then either took a break from their studies or studied elsewhere before entering the first year courses;
3. International (Int’l): Students who completed an international school leaving examination, most often, but not exclusively, the A-level examination. They have either entered the first year courses directly or after a break from their studies; and
4. Repeat: Students repeating the course having failed it previously. Data for repeat students is unavailable for 2007.

Figure 1 illustrates the distribution of groups in the Mathematics classes.

Figure 1. Distribution of groups in the Mathematics classes.

Figure 1 illustrates the distribution of groups for the Maths class, as well as the increase in cohort size in 2009. This increase is mainly as a result of an increase in the RSA matric group. The Physics classes, while not identical, are very similar.
Course Stability

In the first instance, we wish to interrogate the stability of the courses over a five year period; whether or not the courses themselves may possibly have changed during the period under review. To comment on the course stability we have extracted the results of only those students who did not write a South African matriculation examination, but rather wrote an international examination, in most cases A-levels. We have chosen this group as a “control group” and have made the assumption that their level and type of preparation should not have changed significantly as those coming through the recent NSC examinations. Therefore, if the results of the international examination students in Mathematics and Physics are statistically comparable over time then our argument would be that the courses themselves have not changed to any significant degree.

A t-test was performed on the pairs of data to determine whether or not the groups are comparable. At the 95% confidence level, for data with a large number of degrees of freedom, a t statistic below 1.645 indicates that there is no statistical difference between the data sets. The statistical analysis including the results of the t-tests for the international examination student groups are shown in Table 1.

Table 1: Results for students with international school leaving exams

<table>
<thead>
<tr>
<th></th>
<th>Mid-year Maths Results</th>
<th>Mid-year Physics Results</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2007</td>
</tr>
<tr>
<td>sample size</td>
<td>99</td>
<td>74</td>
</tr>
<tr>
<td>no. of passes</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>pass rate</td>
<td>33</td>
<td>41</td>
</tr>
<tr>
<td>Mean</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>standard deviation</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>39%</td>
<td>38%</td>
</tr>
<tr>
<td>t-test ( t_{0.05} ) with 2009</td>
<td>0.744</td>
<td>0.497</td>
</tr>
<tr>
<td>t-test ( t_{0.05} ) with 2007</td>
<td>1.071</td>
<td>3.543</td>
</tr>
</tbody>
</table>

In the case of the Mathematics course results for the international examination groups, there is no significant difference between the years, and therefore we would claim that the courses have not changed significantly in terms of assessment. The mean and standard deviation of the groups are comparable and the stability of the coefficient of variation further suggests that the students from the international examination groups are stable over time. Consequently we conclude that the results for the Mathematics courses can be compared directly over time. We would thus suggest that a change in the performance of other groups in Mathematics is more likely a result of a change in their prior schooling than a change in the Mathematics course itself.

By contrast, the t-tests suggest that the 2007 mid-year results for the Physics course differ significantly from both the 2005 and 2009 results. The consistency of the coefficient of variation indicates that the change is more likely a change in aspects of the Physics course in 2007 rather than a change in the control group. This argument is strengthened by the fact that the same control group in Mathematics does not exhibit this variation. Therefore we are more circumspect in drawing conclusions about any changes in the performance of students in Physics in 2007.

Comparative Course Results

In order to explore the anecdotal view that the new school curriculum has resulted in a declining success rate at university in Mathematics and Physics, the mid-year course results have been analysed in terms of the four categories of students identified above. Only the results of the total group and the disaggregated RSA matric group and the international examination groups are presented in Tables 2
and 3. The results for the 2007 Physics course are shown only for completeness, and have not been included in the analyses.

**Table 2:** Mathematics mid-year results

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2007</th>
<th>2009</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total group</td>
<td>RSA matric</td>
<td>Int’l</td>
</tr>
<tr>
<td>sample size</td>
<td>431</td>
<td>259</td>
<td>99</td>
</tr>
<tr>
<td>no. passes</td>
<td>162</td>
<td>103</td>
<td>33</td>
</tr>
<tr>
<td>pass rate</td>
<td>39</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Mean</td>
<td>46</td>
<td>47</td>
<td>44</td>
</tr>
<tr>
<td>Stdev</td>
<td>16</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>35%</td>
<td>35%</td>
<td>39%</td>
</tr>
</tbody>
</table>

**Table 3:** Physics mid-year results

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2007</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total group</td>
<td>RSA matric</td>
<td>Int’l</td>
</tr>
<tr>
<td>sample size</td>
<td>419</td>
<td>256</td>
<td>96</td>
</tr>
<tr>
<td>no. passes</td>
<td>243</td>
<td>142</td>
<td>59</td>
</tr>
<tr>
<td>pass rate</td>
<td>60</td>
<td>55</td>
<td>61</td>
</tr>
<tr>
<td>Mean</td>
<td>55</td>
<td>54</td>
<td>57</td>
</tr>
<tr>
<td>Stdev</td>
<td>15</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
</tr>
</tbody>
</table>

It should be noted that only the 2009 RSA matric group (those who wrote matric in 2008) have completed the full OBE curriculum. A comparison of the average Mathematics and Physics marks for each group and the pass rates are of most interest for the purposes of exploring the anecdotal view that those students who wrote matric in 2008 are significantly less well prepared for the university Mathematics and Physics courses than previous cohorts. These results, presented in Figures 2 and 3, show the average and pass rates for the total group, the separated RSA matric students (those who moved directly from school to university) and the control groups – the international examination students.
averages for (a) Mathematics and (b) Physics

![Figure 3. Mid-year pass rates for (a) Mathematics and (b) Physics](image)

The similarity in the averages of the control groups serves to highlight the assumption that the courses have not changed significantly. The decline in both the average and the pass rate of the RSA matric group is therefore of concern. However, the visible decline in the 2007 Mathematics results would indicate that this trend cannot be solely blamed on the 2008 matriculation examinations and curriculum alone.

Distribution of Course Results

We turn now to look in more details at the results for the two categories of students that we have discussed so far, namely the RSA matric groups and the international examination control groups. The 2009 cohort was significantly larger than the other cohorts, mainly as a result of a larger intake of students directly out of school. There has been speculation on the effect that this has had on the results of the two courses. We have analysed the result distributions of these two groups over time, both in terms of percentages of the group and as absolute numbers and illustrated these in Figure 4.

![Figure 4a. Distribution of mid-year results for Mathematics.](image)
Figure 4b. Distribution of mid-year results for Mathematics as a percentage of the group.

Figures 4a and b illustrate that there is a clear decline in the performance of the RSA matric cohort since 2005. The same decline is not evident in the international examination control group. However, our argument is that the decline in RSA matriculants’ preparedness for university Mathematics is not a sudden result of the new 2008 matric examinations. The comparison between the 2009 and 2007 RSA matric cohorts in Figure 4 clearly illustrate this claim for Mathematics. The group mode has in fact increased from 2007 to 2009.

An alternative way to look at these data is to look at the absolute number of successful students in each cohort. Figure 5 shows the absolute number of students in each cohort who have achieved a mid-year mark of at least a particular value. For example, in 2005, 106 students who had written matric the previous year were achieving 50% or more for Mathematics after the June tests. In 2007, for a similar class size, this number had declined to 72. Although the group was considerably bigger in 2009, only 81 students were achieving a class mark of 50% or more.

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27 Mode is a statistical term for the result that occurs most often in the sample.
The graph in Figure 5 clearly shows that although there are substantially more students in the Mathematics class who wrote the 2008 matric exams (2009 RSA matrics) than their counterparts who wrote matric in 2004 (2005 RSA matrics), fewer of the RSA matric group are achieving 50% or more in the Mathematics course in 2009.

The 2007 group however raises an interesting point. At the same mid-year stage of the Mathematics course in 2007 even fewer students were achieving a pass mark than in 2009. This result confirms the argument made earlier - that the decline in mathematical preparedness started before 2008, and cannot be solely attributed to the 2008 NSC matriculation examinations.

Figure 5 also emphasises the large number of students in 2009 who are failing midway through the first-year course. There is much speculation about this ‘tail’ and how to address it. We will discuss this in more detail in the next section.

With the variability of the Physics course in 2007, similar claims for Physics cannot be made. However, although the average mark and pass rate for the 2009 Physics class decreased from 2005 (see Figure 6), those students achieving an mid-year mark of at least 50% is slightly greater than for the 2005 class (see Figure 7). However, there is still an unacceptably high number of unsuccessful students in the 2009 Physics course, as shown in Figure 7.
Figure 6. Distribution of mid-year results for Physics.

Figure 7. Cumulative distribution of mid-year results for Physics.

Correlation between admission criteria and student performance in 2009

In both the Mathematics course and the Physics course, the large number of students achieving less than 40% in 2009 is of concern. This constitutes more than half the RSA matric groups in 2009. These are students who have gained access to the university based on their NSC marks, but who are clearly not adequately prepared to succeed in these courses.

A correlation analyses between matriculation points marks and mid-year Mathematics and Physics results was performed in an effort to gain insight into the transition between school and university assessment measures. The analysis is limited to the 2009 RSA matric group of students (those who wrote matric in 2008) because of the large number of poorly performing students in this group. Although there is a statistical relationship, the large degree of scatter in the results and the low correlation does raise concerns on measures used as the entry requirements.
One strategy considered for eliminating potential underperforming students is to increase the minimum points required for entry into the degree programs. However, Figures 8a and b show that even increasing the entry requirements to 48 or 50 points does not effectively eliminate the so-called ‘tail’. There is a large number of students with high matriculation points who are not performing well in the Mathematics and Physics courses. The low correlation between matriculation points and performance in both courses further mitigates against increasing the entry requirements as the only mechanism to address the issue.

Finally, a correlation analysis between the Mathematics and Physics results for this group of students is presented in Figure 9. The correlation between the results is stronger; however, the graph illustrates how small the group of students succeeding in both Mathematics and Physics from the RSA matric group is (top right hand quadrant); while those failing both Mathematics and Physics (bottom left hand quadrant) is by far the greatest group. With the very small number of students passing both courses at this stage in the courses, the notion that these are the only students who should gain access to the engineering programmes needs to be considered in the context of the greater conversation around throughput rates in South African higher education.
Concluding Remarks

Based on the statistical analysis of the control group (the international examination students) we would argue that the Mathematics results for 2005, 2007 and 2009 are directly comparable, while the 2009 physic course can be compared only with the 2005 Physics course. Comparisons between these sets of data confirm a general decline in the performance of students in first year Mathematics and Physics. However, comparison with the 2007 Mathematics data reveals that the ‘new’ matriculation examinations cannot be blamed as the sole contributor to this general decline.

The poor performance of the 2009 first-year group in Mathematics and Physics is not a sudden or dramatic shift, but rather part of a gradual deterioration in the preparedness of the incoming first-year students; this is confirmed in our study by the weak mid-year performance in Mathematics of the 2007 first-year group. This suggests that simply changing the final NSC Mathematics examination is unlikely to produce, or even identify better prepared students.

In the light of these findings any discussion that simply focuses on scepticism regarding the 2008 NSC Mathematics results, is likely to be a red herring: it distracts from the potentially much more serious issues of Mathematics teaching and learning at school level, as well as the assumptions made by higher education institutions about the mathematical skills of incoming students. Universities have limited influence over what happens in secondary schools, and any significant change there will take time.

This paper has attempted to describe the situation ‘on the ground’ mid-way through the first year of an engineering course at a South African university. The question now is what should constitute an appropriate response to this. A suitable response to the situation described in the study has to move beyond discussions about increasing entrance criteria for engineering and Science programmes: our results show clearly that the so-called ‘tail’ of weaker students would not be effectively eliminated by increasing the number of points required for admission. This raises questions about just how confident we should be about the ability of NSC results to predict student success. Further investigations looking at the correlation between the NBT results and the Mathematics and Physics marks may provide a better indicator of potential student success.

The potentially large number of unsuccessful students in 2009 casts a shadow over the notion of broadening access to higher educational institutions. Access without some reasonable chance for success is worthless. The view that the first year should serve as a ‘filter’ to ‘weed out’ unsuitable students who should not be in higher education in the first instance, is problematic. Higher education institutions have to grapple with ways to find educational strategies that would impact student success (Scott et al, 2007).

If higher education institutions are to remain relevant, that is, if we are serious about increasing access to higher education in an attempt to alleviate the critical shortage of Science and engineering graduates in South Africa, we have to find ways to respond adequately to the problem of assisting under-prepared first-year students to succeed.

References


